Teaching Econometrics as Though Coherence Matters

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1. Coherence - and a prototypical example

To give a *coherent* account of any subject one must identify related elements within the subject and explain the elements in a way that highlights the relationships.

Every subject contains interesting and fundamental relationships that appear *along* the way in the conventional order of presentation of its elements. Most subjects also contain other such relationships which are apparent only in a view *across* different strands of the subject. Coherence, then, is a matter of latitude as well as longitude, of the lateral as well as the forward view.

This said, it is also worth observing that merely to identify related elements will not fully convey to students the sense of coherence of the subject felt by the teacher. It is vital also to imbue students with an attitude of mind which I can best term "thinking linking", *so that each student actively formulates for him/herself* a conception of the subject in which every element is perceived as woven into a fabric of knowledge.

While we must, of necessity, focus on the warp and the weft in studying the details, *the ultimate objective is to understand the subject as a continuous, unified, integrated whole*, part of the fabric of a broader discipline and, indeed, of all human knowledge.

It is true, of course, that one may understand a subject from teaching which does not offer a lateral view (or, indeed, any view at all) of coherence, but it will in comparison be an imperfect understanding, and it is not likely to be a lasting understanding.

An analogy can help to make the point. Consider a jigsaw puzzle in course of completion. As each piece is identified and correctly located, the picture grows. The puzzle-solver's eye, however, insists on a narrow view, on finding the link between the last fitted piece and its successor. Scrutiny is restricted doggedly to pictorial fragments and jig-sawn profiles. When eventually the puzzle is complete, the cracks between the pieces, so long the front line of advance, seem to melt away: the mind "sees" the

picture as a whole. Only then, at last, do relationships of form and colour across the entire picture become clear.

Unfortunately, teaching too often resembles this kind of jigsaw puzzle solving. The consequence should be clear. If students sense that they will be able to get a coherent view of the subject only after their course is complete, and that getting that view will then depend entirely on their own efforts, they may well decide to dispense with the coherent view and, in doing so, will prejudice their lasting understanding.

Let us examine in context the idea of teaching as though coherence matters.

Suppose we are to explain the theory and practice of multiple regression analysis to a class of second-year economics undergraduates who have already completed a semester of basic statistical inference. We are, in other words, to lay the foundation for a quantitative approach to economic analysis.

We shall not, of course, be teaching this subject in a vacuum. We know the syllabus of the students' foundation subject (and we presume they remember what they learned there - which is not always a sound presumption!). We believe, moreover, that explaining the subject coherently is a key catalyst to student understanding and retention.

Let us now look at specific ways in which multiple regression can be presented coherently.

(i) Firstly, we may explain to students that applied econometric analysis proceeds by way of a "paradigm of modelling", that is, a logical sequence of steps designed in general to produce a "good" statistical model of the mechanism that generated the observed data. We emphasise that the model cannot hope to be a replica of that mechanism, but rather that it will be a concise abstraction of the mechanism, whose important characteristics (however they may be defined) it will capture.

The paradigm of modelling I like to represent by the acronym SIEVE, that is, Specification, Identification, Estimation, Validation, and Exploitation. In this sequence, we shall say, the statistical theory of multiple regression is a part of the estimation phase.

There is an essential continuity in the phases of modelling - estimation is in no sense an isolated activity. We may ensure that students grasp this by doing two things: emphasising that the goal of our work is the development of a specification, valid for our purpose, in which the criterion of *economic significance* plays at least as important a role as that of *statistical significance*, and demonstrating how the phase of estimation "fits in with" the pursuit of this goal.

This attention to making coherent the paradigm of modelling, and nesting coherently within it the theory of regression, I call highlighting *theme coherence* in the subject. The key characteristic of theme coherence is the *longitudinal* (i.e. linear sequential) *continuity* of analytical procedures in the subject.

(ii) Secondly, we may draw students' attention to the similarities of statistical reasoning and formulae in simple regression (which they have previously learned!) and in multiple regression. The direct purpose of this is to make learning easier, by showing clearly (in an appropriate notation) how multiple regression is "just like simple regression, except with more regressors" (or, speaking geometrically, "... except in a larger number of spatial dimensions"). A less direct (but no less important) purpose is

to give students a painless experience of (mathematical) generalisation - in itself a kernel of logical thinking.

In this simple example we are calling attention to similarities in the structure of *evidently related* analytical procedures. More generally, we may point out the common characteristics of *apparently disparate* procedures in the subject. In either case, I term it teaching via *pattern coherence*. The key element of pattern coherence is the *latitudinal* (i.e. inter-procedural) *unity* of the subject.

(iii) Thirdly, we may offer students a methodological critique of the strengths and weaknesses of multiple regression analysis as a tool for the analysis of non-experimental data, in general, and for the construction of valid economic models, in particular.

In doing this, we are appraising textbook econometric technique against well-founded statistical criteria, and also asking what the worth of that technique is for practical economic applications. We are, in other words, *integrating* students' developing knowledge of econometrics *globally* with their knowledge of statistics and of economics. I describe such integration as *knowledge coherence.*

Anyone familiar with current textbooks of econometrics will confirm that they aim at theme coherence in their exposition, but that they do it with markedly unequal success. On the other hand, it is only a handful of the more technically advanced texts that address pattern coherence. Knowledge coherence is hardly considered systematically in the textbooks at all.

Coherence in teaching econometrics is evidently a topic fruitful to explore in greater depth.

2. The place of coherence in effective teaching

There will be optimal transmission of knowledge between teacher and student when the teacher is knowledgeable, well-prepared, and skilled, and when the student is able, well-grounded, and receptive. Of all these attributes, it is the teacher's skill and the student's receptiveness that are the least easily defined. It seems to me, moreover, that these two attributes have some causal connection.

The teacher can contribute to students' receptiveness by provoking their interest, by stimulating their curiosity, and by convincing them that their learning efforts are worthwhile. This the teacher does partly through his/her personal attitude and example and partly through the way he/she presents the subject matter.

Four aspects of quality in presentation stand out. They are clarity, vividness, perspective, and coherence. Of these four, one can argue that coherence is the most important.

Coherence is the only characteristic that is an attribute both of the subject and of the way it is presented. That econometrics is a coherent discipline is taken as given: the emphasis here is on presentation. *The challenge is to show coherently how coherent the subject is!*

It is coherence in presentation which most contributes to an understanding of the structure of the subject and to an appreciation of its aesthetics. This understanding and appreciation are significant factors in long-term retention of learning. It is coherence in

presentation, moreover, that most readily provides insights on directions for further research (Narula, 1974).

3. Three dimensions of coherence

The introductory example served to identify the three dimensions of coherence and their complementary descriptors:

Theme coherence	is	*longitudinal*	and signifies	*continuity*
Pattern coherence	is	*latitudinal*	and signifies	*unification*
Knowledge coherence	is	*global*	and signifies	*integration*

We shall look now at each of these in more detail, giving appropriate econometric illustrations in each case.

3.1 *Theme coherence*

There are two contexts for demonstrating continuity - a smooth traverse through connected theory, and a smooth transition from theory to practice.

In the discipline of econometrics, the "connected theory" at centre stage is the paradigm of modelling. Opinions differ on the most appropriate topic with which to begin the study of modelling (see Sowey, 1983, p.259). The "inference approach" is traditional, judging from the disproportionate number of textbooks that proceed this way, and is *technique-driven*. Teaching focusses on statistical techniques of inference in regression models of ever-increasing complexity. An alternative, which might be called the "specification approach", is *application-driven* and so begins by discussing the specification of an econometrically testable model of some economic relationship, and only thereafter comes to problems of inference.

Whatever the approach, there must be a close linking of the theoretical principles of *all* of the following: data collection and quality-assessment, model construction, and model evaluation.

The transition from theory to practice demands coherent treatment as well. This will be difficult to achieve when theory and applied subjects are distinct in the degree programme (and, perhaps, taught by different individuals). For this reason, I advocate that an encounter with data should have a part in every econometrics subject.

None of the foregoing observations will seem in the least controversial to an experienced teacher of econometrics. It is surprising, then, to discover how little support someone pursuing theme coherence can glean from the textbooks.

A sort of continuity is indeed there, but it is a short-range continuity, in most cases constrained wholly within the realm of statistics. One by one, a sequence of statistical problems is generated by the relaxation of some idealised assumption. Each particular problem is discerned, fleshed out and displayed, various technical solutions are propounded and evaluated, and then it is time for the next problem. So limited a continuity is not what is intended by my expression "theme coherence".

Over the last decade, more than a dozen *statistical* textbooks have appeared that emphasise a theme-coherent approach to empirical modelling. Among the best written of these are Gilchrist (1984) and Chatfield (1988). Why, then, do *econometrics* texts lag behind?

3.2 *Pattern coherence*

We are here concerned with revealing the common elements that underlie apparently disparate analytical problems and techniques. Teaching that emphasises pattern coherence brings the student two benefits. Firstly, it ought to facilitate learning and understanding, generally. Then, because the discipline is shown to be more "compact" (i.e. unified) than it might otherwise seem, it is easier for the student to form the personal conception of the whole discipline that is so necessary for professional autonomy.

As its name suggests, pattern coherence in teaching rests on the recognition of common patterns in diverse areas of the discipline. In econometrics, as in all mathematically-based fields, such recognition is sometimes more immediate when an algebraic view is taken of the subject, and other times when a geometric view is taken. This point is made not only because it is commonly overlooked (given the overwhelmingly algebraic focus of most textbooks), but also because it should act as a spur to students to acquire their understanding in both algebraic and geometric terms. Further encouragement can be found in Fisher and McAleer (1984) and in Saville and Wood (1991).

To illustrate the scope for highlighting unifying principles in teaching econometrics, I present a number of examples with appropriate citations.

Singularity of the moment matrix in regression. Three different circumstances have this consequence in common. They are perfect regressor collinearity, constancy of a regressor over the sample data, and an undersized sample. This is a very easily understood instance of pattern coherence, so it is surprising that it is not referred to in this light in any of the commonly-used econometric textbooks!

Instrumental variable interpretation of econometric estimators. The family of estimators with a demonstrated IV interpretation includes: the two stage least squares estimator (Fomby et al., 1988, p.481); the k-class estimator (Goldberger, 1965); the three stage least squares estimator (Kakwani, 1968); the full information maximum likelihood estimator (Hausman, 1975); Wald's grouping estimator in the errors-in-variables model (Fomby et al., 1988, p.273). An encyclopedic exposition that emphasises pattern coherence in this context is found in Bowden and Turkington (1984).

Restricted maximum likelihood as a unifying approach to the structure of simultaneous equation estimators. This is elegantly expounded in the papers by Hendry (1976), Anderson (1980), and Prucha and Kelejian (1984).

Restricted least squares as a unifying principle. Restricted least squares unifies: the study of estimator properties in misspecified models (Riddell and Buse, 1980); estimation in principal components analysis (Fomby, Hill and Johnson, 1978); ridge regression estimation (Kmenta, 1986, p.440); Almon polynomial distributed lag estimation (Trivedi and Pagan, 1979; Fomby et al., 1988, p.378); the Chow test (Stewart and Rayner, 1970).

Iterative generalised least squares as a unifying principle. Generalised least squares (GLS) estimation has a very wide range of applicability in econometrics. Situations include models with non-spherical errors, models with stochastic linear restrictions on the coefficients, seemingly unrelated regressions, and models for pooling cross-section and time series data. The method of three stage least squares estimation is itself a version of GLS. Various iterative extensions of GLS suggest themselves when parameters in the covariance matrix of regression disturbances need to be estimated, and when models are nonlinear. General overviews are given by Rao (1973) and del Pino (1989).

Biased estimation as a unifying principle in regression analysis. The optimality of biased estimation was discovered by Stein (1956) in the context of estimating the mean of a multivariate normal distribution, and was popularised by Efron and Morris (1977). The form of the Stein estimator appears quite counterintuitive and an intuitively appealing explanation has only very recently been given (Stigler, 1990).

Intuitive or not, the idea of biased estimation has taken firm root in econometrics. Here, biased estimation (sometimes called "shrinkage estimation") encompasses ridge regression estimation, pretest estimation, and minimum mean square error estimation generally.

Expositions emphasising pattern coherence are found in Hocking (1976), Draper and van Nostrand (1979), Trenkler (1981), and Judge and Bock (1983).

Unifying principles for asymptotic tests of correct specification in regression. Two alternative approaches are available. One is to classify tests (where possible) as either Likelihood Ratio, Wald or Lagrange Multiplier tests - see Buse (1982), Engle (1984), and Godfrey (1988). The other is to interpret them (where possible) either as data transformation tests or as data addition tests - see Kraemer and Sonnberger (1986, Chapter 5).

A unifying approach to behavioural and pure time series modelling. This idea has its source in Zellner and Palm (1974). The approach is dubbed "SEMTSA modelling" ("structural econometric modelling and time series analysis") by Zellner, who pursues it in Zellner (1979). Further development is reported in Anderson, Johannes and Rasche (1983).

These examples by no means exhaust the patterns of coherence that we may recognise across the discipline of econometrics. One could go on to mention, for instance, various analytical frameworks for integrating Bayesian and non-Bayesian approaches to econometric inference, and the use of a common state-space representation for dynamic structural and ARMA models.

Just as in the case of theme coherence, the textbooks of econometrics are ill-suited to teaching that emphasises pattern coherence. No text focusses specifically on such an approach, though there are a few that pause to point to relevant patterns, as asides from the primary flow of exposition. Most informative among such texts is Fomby, Hill and Johnson (1988), and it is this book which I have cited earlier in this section.

3.3 *Knowledge coherence*

Knowledge coherence here refers to the seamless weaving of econometrics into the fabric of all human knowledge.

Let us think of this fabric as a patchwork quilt. The most obvious initial directions to pursue such integration are towards the three immediately neighbouring patches - the three sustaining disciplines of econometrics, viz economics, statistics, and computing. In a fourth direction, within the field of epistemology, lies the study of econometric methodology. There are educational benefits, as well, in pursuing knowledge coherence further across the quilt.

What sort of understanding can be expected to develop from integration of this kind? At the very least, it will provide a broadening of students' stock of knowledge that is very desirable in a world of ever-narrower specialisation. At best, it will also offer a cultural enrichment that is too often lacking in econometrics courses nowadays. Surely it is not yet misguided to believe that the university's mission is to offer an education for the whole person, and not just a professional training.

For more insight on the benefits of a coherent presentation it is worth looking at some particular areas of integration.

Putting econometrics in an economic context can provide deeper insights into such fundamental questions as "what are the limitations of econometric models for feasible policy design?", "how effectively can institutional constraints be econometrically expressed?", and "what has econometric testing contributed to resolving theoretical controversies in modern economics?".

Such questions are taken up in a highly enlightening fashion by, for example, Ormerod (1979), Eckstein (1981), Perryman (1982), Kamarck (1983), and Thurow (1983).

Looking at statistics from an econometric perspective lets students grasp more clearly how the non-experimental nature of economic data complicates data collection and the design of econometric techniques. It also underlines how extensively these techniques rest on asymptotic justification. Research students working on new econometric estimation and test procedures (for example, in robust regression or model specification analysis) can gain valuable leads by looking at what is going on in the neighbouring discipline.

Similarly, an acquaintance with current developments in computer hardware, computing algorithms, and software packages, opens possibilities for enhancing the subtlety of empirical work in econometrics, and for implementing methods of analysis previously considered intractable.

Econometric methodology - the appraisal of the validity and practical worth of econometric methods - is a study of vital professional importance, but one that is sadly neglected in most econometrics courses. Perhaps this is because, here again, the textbooks of econometrics are, with one or two exceptions, quite unsupportive. Yet the scholarly literature offers much informative reading. References quite accessible to undergraduate students of econometrics include Cooley and LeRoy (1985), Pagan (1987), Aigner et al. (1988), and Darnell and Evans (1990).

At one remove, so to say, across the statistical patch are disciplines cognate to econometrics, including psychometrics, biometrics, cliometrics, sociometrics, and so on. At appropriate moments it can always be interesting to draw parallels with analytical approaches in these fields. The collection of papers edited by de Leeuw, Keller and Wansbeek (1983), for example, provides an entry into the communalities of econometrics and psychometrics.

Across the economic patch, in turn, lie politics, psychology, law, and history. Econometrics has a non-empty intellectual intersection with them all. And so it goes on and on, over the patchwork quilt of knowledge into the dim distance.

4. Obstacles to coherence

A coherent presentation of econometrics may not be achieved because: (i) textbooks are unsupportive, and/or (ii) the lecturer fails to highlight coherence, (iii) students are unprepared and unresponsive, (iv) unresolved theoretical problems within econometrics are impediments.

We have already seen that the textbooks of econometrics are generally not conducive to a presentation of the subject that is coherent in any of the dimensions defined above. It is not that the texts are antagonistic to such a presentation, rather that they are largely silent on the crucial elements of linkage. Nor, regrettably, do almost any of them point an interested reader towards a coherent view elsewhere. In fact, there is no central source at all for locating econometric studies that emphasise the element of coherence.

The lecturer who wishes to teach coherently has much to contend with, apart from a dearth of appropriate textbooks. A syllabus crowded with statistical technicalities that must be "covered" will discourage even a secondary focus on pattern and knowledge coherence. If there is poor coordination between the teaching of econometrics and economics subjects, then theme coherence will be hard to achieve as well.

In truth, it must be said, the biggest obstacle to coherence in teaching is often that the lecturer him/herself does not, for whatever reasons, recognise or acknowledge the importance of coherence!

There are limits, of course, to what the lecturer can achieve in the way of coherent linkages. These limits are set in part by the students' fund of past and presently developing knowledge. The "patchwork quilt" of their knowledge resembles less a continuous surface than a lattice pierced with irregular holes. It will, therefore, be unsafe to attempt a linking trajectory before first determining, in the relevant region, where the holes are.

Students who have never experienced the intellectual excitement of a coherent exposition may be unresponsive to efforts made in this direction by their lecturer. In that case, the lecturer needs, as well, to rise to the challenge of convincing students of the value of the approach.

There is a more intrinsic obstacle to certain kinds of coherent linkage. This is the existence of unresolved theoretical problems within the discipline. Here are two examples. Given our limited knowledge of the properties of econometric estimators and tests in finite samples, it is not possible (at present) to trace pattern coherence between asymptotic and finite-sample theory. Further, in view of what Leamer (1978) calls "the axiom of correct specification" (i.e. that the "correct" specification of a regression equation is assumed in classical statistics always to be arrived at without any data mining), a hiatus develops between the classical theory of model building and what econometric model builders actually do. It is thus difficult to give a theme-coherent exposition of model building without using a Bayesian framework.

5. Coherence in practice

How may one best teach coherently? This is now the obvious question.

My own experience in teaching econometrics suggests an harmonious alignment: theme, pattern, and knowledge coherence are put in correspondence with lectures, exercises, and assignments, respectively. Since, moreover, exercises and assignments promote learning-by-doing, notions of disciplinary coherence thus planted in students' minds are likely to be firmly rooted.

The "paradigm of modelling" (on which *theme coherence* centres) is the backbone of the econometrics syllabus and, consequently, represents a natural framework for structuring the lecture programme. Student tutorial exercises offer a natural opportunity for lecturer-prompted learning by discovery, and so are the ideal avenue for discovering *pattern coherence* in econometrics. Assignments are a vehicle for learning through personal research - and investigating interdisciplinary linkages, the essence of *knowledge coherence*, is a stimulating student research project.

This is a way to teach econometrics as though coherence matters. Perhaps my title suggests that coherence is optional? What, then, is the alternative?

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